EFFECT OF PLANTING DEPTH AND TIME OF EARTHING-UP ON POTATO (*Solanum tuberosum* L.) YIELD AND YIELD COMPONENTS AT JIMMA, SOUTHWEST ETHIOPIA

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BY

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JIMMA UNIVERSITY

EFFECT OF PLANTING DEPTH AND TIME OF EARTHING-UP ON POTATO (*Solanum tuberosum* L.) YIELD AND YIELD COMPONENTS AT JIMMA, SOUTHWEST ETHIOPIA

A thesis submitted to school of graduate studies Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in partial fulfillment of the requirements for the degree of master of Science in horticulture (Vegetable science)

By

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I dedicate this thesis to my family for nursing me with affections and love and their dedicated Partnership for success in my life.

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BIOGRAPHICAL SKETCH

The author, Tadele Fanos Tefera, was born on April 4, 1987 at Arsi Robe, Arsi zone of oromiya Regional State. He attended his elementary and junior secondary schools at Metu Abune phexros primary and secondary school in Metu and preparatory school at Metu high school in Metu twon Illu Ababora zone Oromiya Regional State. Following the completion of his preparatory education, he joined Mekelle University in 2006 and graduated with B.Sc Degree in dry land crop and Horticulture science under Agronomy stream in July, 2008. After graduation the author was recruited by the Ministry of Agriculture and Rural Development (currently called Ministry of Agriculture) at Illu Ababora zone Oromiya Regional State Hurrumu woreda and has been working as horticulture expert, until he joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a graduate study leading to a Master of Science degree in Horticulture (Vegetable science).

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ABBREVIATIONS

ANOVA	Analysis of variance
SAK	Sustainable Agriculture kits
BPEDORS	Region. Bureau of Planning and Economic Development, Council of Regional State of Oromiya. Ethiopia
CASCAPE	Capacity Building for Scaling up of Evidence based best Practices in Agricultural Production in Ethiopia
IPC	International Potato Center
COQA	Co-innovation for Quality in African Food Chains
CV	Coefficient of Variance
DAFF	Department of Agriculture, Forestry and Fisheries
Df	Degree of freedom
EARO	Ethiopia Agriculture Research Organization
FAO	Food Agriculture Organization
FAOSTAT	Food and Agricultural Organization statistics
Ton Ha-1	Ton Per Hectare
HARS	Himalayan Agricultural Research Station
IAR	Institute of Agricultural Research
LSD	List Significant Difference
M.A.S.L.	Meter Above Sea Level
NIVAA	Netherlands Potato Consultative Institute
PH	Percentage of Hydrogen
RCBD	Randomized Complete Block Design
SAS	Statically Software
SE±	Standard Error
UFA	University of Alaska Fairbanks
USA	United State of America
ZCFU	Zimbabwe Commercial Farmers Union

EFFECT OF PLANTING DEPTH AND TIME OF EARTHING-UP ON POTATO (*Solanum tuberosum* L.) YIELD AND YIELD COMPONENTS AT JIMMA, SOUTHWEST ETHIOPIA

ABSTRACT

Potato (Solanum tuberosum L.) is the fastest growing staple food crop and source of cash income for smallholder farmers in Ethiopia. An experiment was conducted at Jimma, Southwest Ethiopia during 2014/15 cropping season to determine the effect of different planting depth and time of earthing-up on yield and yield components of Jalane potato variety. The treatments consisted of 3 levels of planting depth (10, 12 and 14 cm) and four time of earthing-up (no earthing-up, at 15,30 and45 days after plant emergence) were applied to Jalane potato variety. A 3x4 factorial experiment was laid out with 3 replications.Data collected on yield, and yield components were analyzed using SAS Version 9.2 statistical software. Earthing-up at 15 days combined with planting depth of 10 and 12 cm recorded significantly (P<0.01) the highest total tuber number. Planting at 12 cm depth resulted in significantly the highest tuber weight, where as 10cm planting depth gave the highest unmarketable yield.Earthing-up at 15 days produced significantly (P<0.01) the highest main stem number. Moreover, earthing up at 15 daysproduced average tuber weight of 10.28%, which is higher as compared to the no earthing-up.Earthing-up at 15 days, 30 days and 45 days showed reduced unmarketable tuber yield by 13.62%, 7.51% and 3.52 %, respectively as compared to no earthing-up. Time of earthing-up with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and 45days x14cm) recorded the minimum number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively.Earthing-up at 15 days and at planting depth 12 cm produced the highest marketable yield (23.92 and 23.57ton/ha, respectively),alsoearthing up at 15 daysand planting depth at 12 cm produced the highest total tuber yield (28.28 and 26.72ton/ha, respectively). Correlation analysis result showed that the association between all parameters was positive and highly significant. While the number of green tuber and unmarketable yield was negatively and highly significantly (P<0.01) correlated. Therefore, based on the result of this investigation, optimum planting depth at 12cm and earthing up at 15 day is recommended for the potato growers in the study area. Since, the present study was done only for one season at one location; it would be advisable to repeat the experiment at various agro-ecological conditions to come up with conclusive result leading to a recommendation.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is an annual, herbaceous, tuber crop of family solanaceae that contains all the essential food ingredients required for maintaining proper health. Potatoes were introduced outside the Andes region four centuries ago, and have become an integral part of much of the world's food supply. It is the world's fourth-largest food crop, following maize, wheat and rice. Wild potato species occur throughout the Americas, from the United States to southern Chile. The potato was originally believed to have been domesticated independently in multiple locations, but later genetic testing of the wide variety of cultivars and wild species proved a single origin for potatoes in the area of present-day southern Peru and extreme northwestern Bolivia (FAO,2008).

Potato is grown in 79% of the world's countries (Muhammad *et al*., 2013). The crop is grown in about 140 countries in more than 100 countries are located in tropical and subtropical areas, but the highest production in the temperate zones, including industrial countries is concentrated (Shahram and Zayn-alabedin, 2013). The average composition of the potato is about 80% water, 2% protein, and 18% starch. As a food, it is one of the cheapest and easily available sources of carbohydrates and proteins and contains appreciable amount of vitamins B and C as well as some minerals (Muhammad *et al*., 2013). The potato is the world's most important root and tuber crop worldwide. More than a billion people consume it almost daily. Hundreds of millions of people in developing countries depend on potatoes for their survival (FAO, 2008). Based on available information, the potato (per unit area) 74.5% compared to wheat and 58% compared to rice producing more energy (Shahram and Zayn-alabedin, 2013).

China is the biggest producer with between 66 and 71 million tons being grown each year. World average yields are around 20 t/ha, however there is a lot of variation and many of the developed countries are producing above 45 t/ha (Yaha, 2012). The national average yield potential of Jalane potato variety is on research field and on farm level (44.8 and 29.13 ton per hectare) respectively (HARC, 2004).

Developing countries are now the world's biggest producers and importers of potatoes and potato products around the world (FAO, 2008). Thirty percent of world potato production is from developing countries and it is expanding more rapidly than most of the other food crops (Khalid *et al*., 2002). In the world potato is grown in more than 125 countries, which means it is grown 79 percent of the countries in the world (FAO, 2008).Today the survival of millions of people in the developing countries depends on potato.Potato production in most developing countries is characterized by low yields. To increase the yields of potato, they have to adopt the right methods of production (SAK, 2008). So that improvements in the quality of planting material and agronomic practice important (FAO, 2008).

In Ethiopia, potatoes are grown under varied climatic conditions and it is mainly a crop for small farmers. Ethiopian potato is considered Ethiopia's secondary crop with an annual per capita consumption of only 5 kilogram (Fekadu *et al.,* 206). Among all the countries in Africa, Ethiopia has probably the maximum potential to grow potatoes on a large scale. 70% of Ethiopian agricultural land, mainly located in highlands, is appropriate for the production of potato and the crop could play a vital role in making sure the food security of nation. It is a high potential food security crop in Ethiopia due to its nutritional quality tuber and short growing period, and wider adaptability (Tewodros *et al*., 2014). Often driven by food security and market forces, farmers in Ethiopia have been innovating for centuries (Berhanu and Getachew, 2014).It is one of the major food crops in the mid and high altitude areas of Ethiopia. It is recognized as famine relief crop at the end of the rainy season when cereal crops are not ready for harvest, especially in the highland areas, where cereals mature after an extended period (Balami, 2012).Population of Ethiopia is expected to double within the next 30 years. Almost 80% of the population lives in the countryside while the rest situated in urban area. An estimated five million people suffer from lack of vitamins and essential minerals, of which 80% are children .In collaboration with regional research centers, and universities, the centers have generated a number of technologies including improved varieties, appropriate agronomic practices and crop protection measures for the vegetable production sector (Fekadu *et al.,* 2006).

Despite its importance as a food crop, the productivity in Ethiopia of this crop is as low as 10 ton per hectare mainly due to poor agronomic practices (Balemi, 2012*)*.The recent experiment result also show that potato productivity in Ethiopia is too low 7 ton per hectare (Berhanu and Getachew, 2014). This is by far below the world's average yield which is about 20t/ha (FAO, 2011). Farmers and the Ministry of Agriculture claim that in the southwestern parts of Ethiopia major highland area total tuber production has declined considerably over the last few decades for unknown reasons. The low productivity of potato is attributed to many factors like depth of planting, ridging, soil moisture, row planting, lack of improved crop variety and lack of high-quality seed potatoes, inappropriate agronomic practices, late blight and absence of proper pest management practices, unavailability of proper transport, storage, marketing facilities planting date, and fertility status are the prominent ones (Berga *et al.,* 1994; Tekalign, 2005; Habtamu *et al*., 2012, Temesge, 2008).Poor agronomic practices observed in most farmers` fields are used on depth of planting, earthin-up, its frequency of earthing-up and others (Gebremedihin *et al.*, 2008).

Among all the factors which affect the potato yieldremarkably, depth of planting and time of earthing-up are the most important onebecause of affect the soil moisture, soil temperature and soil air condition create unfavorable environmental condition below ground part of the plant(Fekadu *et al.,* 2006). The meteorological elements governing growth, development, production, and quality of potato tubers at a given site are basically air and soil temperatures, solar radiation, photoperiod, soil moisture, and crop water use or evapo-transpiration.According to (Pavek and Thornton, 2009) there is no specific optimum depth of planting for all the weather conditions since it differs based on environmental and controlled conditions. The field practices which are important for growth potatoes are for example: Planting depth and hilling-up. Tesfaye *et al.* (2012) said that lowest total tuber yield (26.49 ton h^{-1})was obtained from no earthing-up. Lowest total tuber yield was recorded in the experiment conducted at treatment 10cm depth of planting (28.48 ton ha^{-1}) (Hanber *et al.*, 2012).

Tesfaye *et al.* (2012) inappropriate time of earthin-up significantly reduces the yield. Hanber *et al.* (2012) the result indicated that un-optimum depth of planting recorded low yield. Farmers use shallow depth of planting for a quicker harvest. Thus potatoes are shallow rooted compared to cereals. As a result, potatoes are often unable to exploit nutrients and soil

moisture at depth within a soil profile (Yara, 2012). The depth of planting potatoes is one of the factors; this product has a significant role in the performance yield and yield components (Hanbar *et al.,* 2012). Hilling operations may also damage potato plants, and significant reductions in yield are known to result from hilling and other types of cultivation (Nelson and Giles, 1986). The time of earthing-up significantly affect growth parameters (Tesfaye *et al.*, 2012). Earthing-up was providing a good cover for the newly formed tubers and to ensure that the developing tubers covered with an adequate layer of soil (Darwin, 1991). Due to poor earthin-up operation decrease the marketable and total tuber yield because of tubers expose to sun light and changed to green color that harmful for human health. This green colour is due to cholophly production and is associated with the production of bitter tasting compounds called glcoalkaloids in the skin and cortex (Darwin, 1994). Soil adding and times had significant effect on the product yield (Tafi *et al.*, 2013). Proper management of each of these factors may result in an increase in quality and quantity of tuber yield (Carling *et al.*, 1990).
Generally, identifying the proper planting depth in combination with earthing-up and other cultural management practices increase yield (Pavek and Thorthon, 2009). Because planting depth influences both soil temperature and moisture (Kouwenhoven 1970; Lewis and Rowberry 1973; Stalham *et al*. 2001), it should be used by growers as a production tool to position seed pieces in the most favorable growing environment.

The production and productivity of potato has increased since the development of high yielding Jalane potato varieties by the Ethiopian Institute of Agricultural Research (HARC). Thus, in the Jimma area, Jalane potato varieties are the most in production. Among newly released variety Jalane potato varieties more disease resistance, adaptable and high yielder so productivity should improve through research work. Science there is no research work on the effect of planting depth and time of earthin-up on yield and yield components of Jalane potato variety in Jimma area. In the absence of recommended depth of planting and time of earthing-up for Jalane potato varieties, the productivity will affected and difficult to apply proper farm management practices. Therefore, this research work is designed to answer “what is the proper planting depth and time of earthin-up for Jalane potato varieties under Jimma agro ecology. Present study will be designed on the objective of: -

- To determine the effects of planting depth and time of earthing-up on yield and yield components of Jalane potato variety at Jimma condition.

2. LITERATURE REVIEW

2.1.Potato production in Ethiopia

Potato is considered as a high potential food security crop due to its capacity to provide a higher yield per input with relatively a shorter crop cycle i.e. less than approximately 120 days compared to other cereal crops like maize. In Ethiopia, potato is grown in four major regions i.e. the central, the eastern, the northwestern and the southern part. Nearly 83% of the potato farmers in Ethiopia belong to these four regions (Bezawit, 2012).

Root and tuber crops are very important non-cereal staples in Ethiopia (enset, potato, sweet potato, yam, taro). Potato is leading tuber crop in the country. Play as a major role in nutrition, national food security and poverty alleviation income generation and provides employment in production, processing and marketing sub-sector. Ethiopia is among the major producer Egypt, Algeria, Malawi, next to Kenya and Uganda. Feature of potato production in Ethiopia is scattered production, large irregularities of production, high variability in quality low input and extensive system (Temesgen, 2008).

Currently, the average estimated potato yield in peasant farmers‟ field in Ethiopia is about 82 quintals per hectare of land for the year 2010 (CSA, 2010). There are different opportunities for Ethiopia to produce potato for instance potential resources (land, labor), among African countries, Ethiopia has possibly the greatest potential for potato production (FAOSTAT) 70 % of its arable land is suitable for potato (> 1500m a.s.l.) (Temesgen, 2008). This ecology is home for 90% the Ethiopian population. Comparative and competitive advantages for regional and global markets (distance and climatic), potato is among officially announced millennium strategic crops.Potato can be grown in any type of soil except salty soil and water retaining type of soil. However, sandy loam type of soil is more suitable for its growth (MOARD, 2009).

2.2.Importance of potato

Potato is the fastest growing staple food crop and source of cash income for smallholder farmers in Ethiopia (Berhanu *et al.,* 2014). Among African countries, Ethiopia has possibly the greatest potential for potato production; 70% of its arable land mainly in highland areas above 1500 meter is believed to be suitable for potato. Since the highlands are also home to almost 90% of Ethiopia's population, the potato could play a key role in ensuring national food security (FAO, 2008). Nutritionally, the crop is considered to be a well-balanced major plant food with a good ratio between protein and calories, and has substantial amounts of vitamins, especially vitamin C, minerals, and trace elements (Bezabih and Mengistu, 2011). In addition to energy and quality protein, it also provides a substantial amount of vitamins and minerals. As a result of this, it is becoming an increasingly important source of rural employment, income and food for growing populations.

It is a very important food and cash crop in Ethiopia, especially in the high and mid altitude areas. Potato has a promising prospect in improving the quality of the basic diet in both rural and urban areas of the country. Apart from consumption of boiled potatoes; it is now extensively used in the wide arrays of traditional stew preparations in both rural and urban areas. In this regard, potato is supplementing and substituting pulse crops that are commonly used for these purposes. Potato consumption has expanded to include chips, crisps and mixture preparations with other vegetables which are becoming popular in urban areas in recent years. The per capita calorie consumption of potato, in the period 2000 to 2002 was estimated as 9.0/day, which is evidence of the growing consumption of potato in the country (Berga *et al.,*1994).

Potato is food of the future. Over the next two decades, the world's population is expected to grow on average by more than 100 million people a year. More than 95 percent of that increase will occur in the developing countries, where pressure on land and water is already intense. A key challenge facing the international community is, therefore, to ensure food security for present and future generations, while protecting the natural resource base on which we all depend. The potato will be an important part of efforts to meet those challenges. Potatoes are a truly global food. The potato has been consumed in the Andes for about 8 000 years. Taken by the Spanish to Europe in the 16th century, it quickly spread across the globe: today potatoes are grown on an estimated 192,000 sq km (FAO, 2008).

Potatoes also provided indirect benefits. Being relatively easy to store, potatoes provided excellent fodder for livestock (primarily pigs and cattle). Often, a significant proportion of the potato crop would be used as fodder. This meant that potatoes also increased meat consumption, as well as manure, which was a valuable input for crop production (Nunn and Qian, 2011).The potato should be a major component in strategies aimed at providing nutritious food for the poor and hungry. It is ideally suited to places where land is limited and labour is abundant, conditions that characterize much of the developing world. The potato produces more nutritious food more quickly, on less land, and in harsher climates than any other major crop - up to 85 percent of the plant is edible human food, compared to around 50% in cereals (FAO, 2008).

FAO, (2008) demand for potatoes is growing. World potato production has increased at an annual average rate of 4.5 percent over the last 10 years, and exceeded the growth in production of many other major food commodities in developing countries, particularly in Asia. While consumption of potato has declined in Europe, it has increased in the developing world, from less than 10 kg per capita in 1961-63 to almost 22 kg in 2004. Consumption of potato in developing countries is still less than a quarter of that in Europe, but all evidence suggests it will increase strongly in the future

2.3.Sprout seedand variability between tubers

Yaha(2012) potato is produced from sprouted seed high tuber yield. The magnitude of this response and its effect on increasing crop yield is related to the physiological age of the seed at planting. Seed storage temperature is the key to controlling physiological aging. Raising storage temperature above 4˚C promotes the break in dormancy and the growth of sprouts. The accumulation of the number of day degrees from this break of dormancy governs the physiological age of the tuber at planting. Different varieties vary in the number of day degrees needed to age to a desired level prior to planting.

Old aged tubers are advantageous when planting early varieties.Tubers that have been minimally aged are suited to long growing seasons where it is desirable to keep the potato growing to achieve maximum yields. When planting sprouted seed it is necessary to control sprout numbers and length (maximum 2 cm) to ensure optimum growth according to plant spacing, and to ensure minimal sprout damage when planting (Yaha,2012).

NIVAA, (2002) all management by the grower should be aimed at reducing variability between tubers. Ideally, a potato crop for processing has tubers all of the same size and shape and with the same dry matter content between and within tubers. Reduction of variability in tubers is best achieved when variability in growing conditions is reduced by planting seed tubers of the same size at the same depth, with the same distances between tubers within the row, and providing an even distribution of fertilizers and moisture. Adequate hilling (ridging) with the aid of a rotary row-crop cultivator in heavy soils helps to ensure homogeneous conditions in the soil.

2.4. Factors affecting yield and yield components of potato

2.4.1. Planting depth

Depth of planting should be recognized as the distance from the level surface of the soil to the lowest part of the seed piece. Consider depth of planting as the distance from the top of the ridge made by the covering disks of the planter, resulting in unnecessary sunburn and lower yields (Parks, 1955).Proper planting depth may be the emergence, seedling establishment and survival suits and each stage of growth with favorable environmental conditions to be met.Planting deeper significantly increased the distance from the top of the hill to the uppermost tuber, but the increase in tuber depth was not equal to the deeper planting depth of the seed (William *et al.*, 1999). Proper planting depth is usually the most will lead to achieve maximum product growth performance (Hanbar et *al.*, 2012).Hanbar et *al.*, (2012) the depth at which potato seed pieces should be planted will depend upon the soil type, season of the year and method of planting. In heavier soils, the planting depth should be shallower than in lighter soils. For the early crop shallow planting is recommended as the depth of planting affects the germination and emergence of the plants. Parks (1955) relatively deep planting is necessary in organic soils. If high yields and large tubers are expected, a deeper planting depth and a wide hill may provide a more favorable environment for mature tubers than a shallow planting depth. It also protects the tubers and roots against temperature and moisture extremes throughout the season. Concerns regarding shallow planting depths may include reduced early season moisture to plants and lower marketable yields owing to an increase in undersized, green and surface-exposed tubers (DAFF, 2013). Deeper planting may provide better soil moisture, less green and surface-exposed tubers, and occasionally, larger tuber size and higher market yields. The disadvantages of deeper planting may include delayed plant emergence and development, yield reductions, and a likely increase in the soil volume that harvesters would have to lift (DAFF, 2013).

Yaha (2012) shallow planting will result in a quicker yield, shallow planting can also cause the actual potato tuber to set closer to the surface of the earth and be subjected to sun greening. Sun greening is a condition where the potato develops a green cast if it grows too close to the surface. These green potatoes can be poisonous. Deep planting or even shallow planting in deep furrows, can be hazardous in heavy, wet soils, which can lead to rot and bacterial infection. Always ensure the surrounding material is well-drained, sandy loam (Yaha, 2012). Adjust the planting depth to the most important factor, soil moisture or soiltemperature (DAFF, 2013).

According to Dawin, (1991) planting depth and methods of soil preparation affect the soil temperature and the moisture conditions around the planted tuber. The planting depth should be adjusted according to the soil conditions. Planting should be deeper in dry conditions, as soil in the deeper layers dries out more slowly than the surface soil.Result showed that planting depth hand an effect on the stolen length and the stolen position and hence on the position of the tuber in the soil. The stolen lengths varied with the planting depth, and with deeper planting the stolen were very short. The stolen numbers were not affected by the planting depth, but at o cm very few stolen formed tubers.Potatoes are reliant on soil temperature, depth of the tubers and rainfall for emergence. Due to the variation in tuber depth, emergence occurs over a period of two to three months or even longer and control measures will have to be implemented repeatedly (Rahman, 1980). Uniformity of planting depth influences in the uniformity of emergence (Roger, 1988).A suitable planting method ensures survival and emergence of all sprouts developing from a seed tuber.

The effects of planting depth on stem density have been directly or indirectly investigated by a number of researchers results (Admire *et al*., 2014). Delayed crop emergence and possibly a reduction in stem numbers as planting depth increased was reported (Bohl and Love, 2005) and (Lewis WC, Rowberry RG,1973). Pavek and Thornton, (2009) showed an acceleration in emergence rate at shallow plantings. Tuber number, stolon and node per stem increased with an increase in planting depth (Pavek and Thornton, 2009). The effect of warm soil temperature, which resulted in the accumulation of more growing degree-days at shallow plantings, may account for the increase in stem density observed. Iritani *et al.*,(1983) showed an increase in stem density when tubers were planted in warm soils. High stem densities have also been observed from deeper planted seed tubers, suggesting that temperature and moisture were important factors (Lewis and Rowberry, 1973).

The greatest tuber depth at which infection was found was 67 mm. Soil depth at which tubers became infected was used to determine the extent of spore movement in the soils. Tuber infection significantly decreased with increasing soil depth. Most infected tubers were found at the surface of soil; infection was rare on tubers at 5 cm or deeper in the soil. Amount of tuber infection varied among soil types (Porter *et al.,* 2005).

2.4.2. Earthing-up

Earthing-up is simply push the soil toward the base of the plants, where the potatoes will form at about the same depth as planted seed. This is best done early in the day, when the plants are standing very straight (Dave Hollingsworth, 1987). Reasons for hilling may include improved weed control, improved drainage, minimization of greening of tubers, and rising of soil temperatures (Carling *et al.*, 2013). Hilling up or ridging potatoes after the last cultivation is practiced by most growers. Hilling protects the tubers from sunburn and frost injury and makes digging easier, as the hill or ridge helps guide the digger. If these are not hilled a high proportion of the tubers will be damaged by sunburn or freezing (Parks, 1955). Parks, (1955) the type of hill or ridge will vary with the region. On heavier soils where rainfall is high, a moderately high, relatively narrow hill with a rounded top is most desirable. This type of hill will also afford good drainage. A broad type of hill, intermediate in height with a saucer-shaped depression is the most satisfactory on lighter soil types.

Parks (1955) hilling can be done quickly and efficiently by special attachments on horse drawn scufflers, tractor-powered row-crop cultivators, the lister double moldboard plow or the implement known as a horse-hoe. The attachments used for hilling are of two types, mold-board or revolving disks.Hillers of the moldboard type are preferred as they shove the soil from the center of the row up to the plants, with a minimum amount of damage to the plants, whereas the disk type of hiller with its cutting and covering action damages both the root system and the foliage of the plants.

Pieter and Flip (2004) the most effective hill parameter to prevent green tubers is increasing the height above the seed piece (at least 20cm) and increase top width of hill (at least 25cm). Larger hills will improve water management by holding more water and lowering temperatures. This will lead to shorter stolons and less greening. Shape the ridge top according to the climate. With a high rainfall leave a sharp top and with a water shortage flatten top or even leave a shallow furrow on top. The optimal water holding capacity, heat transfer and reduced damage at harvest are achieved with an aggregate size around 6mm. Some soils can cause severe cracks in the hill, leading to green tubers and damage by the tuber moth. Cracking can be reduced with a higher degree of crumbling and a low degree of hill compressing. After applying the top dressing, potatoes should be ridged up to 20-30 cm high

The sides of the mound must be 25 to 30cm inches high to effectively raise the soil temperature. The mound should be at least 12 inches across at the top, which is wide enough to plant two rows of many crops. If the ridge is too narrow, the mound will dry out quickly. Rapid changes from wet to dry may place undue stress on the plants. The wider mounds will warm more slowly, but a constant warmer temperature with an adequate level of soil moisture will produce healthier plants and mature a crop (UFA, 2014).

Earthing-up create favorable environment (soil temperature, moisture etc.) for the growth and development of the plant.Tesfaye *et al.*,(2012) result show that highly significantly affect all all tuber quality parameters studied: number of medium, large and green tubers except number of small tubers, tuber dry matter and specific gravity. Most tuber quality parameters showed superior performance at earthing up of 15 days. Proper hilling of potato plants is a crucial practice to assure high production and good quality (Dawin, 1991).Earthing-up facilitates the aeration and weeds eradication from the crop, provides a support to the plant, provides soil covering and nutrients to the developing tubers and facilitates their growth (Khalid *et al*., 2002).No earthing-up practiced some plants down due to less support and bare roots on soil surface (Muhammad*et al.*,2013).

Hamilton (2013) hilling up is done initially by loosening the soil around the potato plants, and piling it up around the plants. Seedbed height after the first hilling up should be around 30 cm. For the second hilling up, remove soil from the furrows and pile it up around the plants. This should be do this more carefully to avoid damaging the plant roots. Seedbed height after the second hilling up should be about 60 cm (Hamilton, 2013). Good hilling at the right time substantially reduces tuber infestation. To avoid damage to tubers by the hiller the rows must be at least 1 meter apart, and the plants must not be out of line in the row. Hilling must be done late in the season when the tubers are large but before they become exposed. The hills should be wide, with the soil thrown well up around the bases of the plants.

If there is no mulch, it is important weed and hill-up at the same time as applying fertilizer. It is important to use at least twice in a planting season; at 30 DAP and 50 DAP (FAO, 2006). Hilling operations may also damage potato plants, and significant reductions in yield are known to result from hilling and other types of cultivation (Nelson and Giles, 1986). Many commercial growers wait until vines are 12 or more inches tall before hilling. This scheduling is preferred because at this time the danger of covering plants is minimal. However, the vines of larger plants may sustain greater damage from hilling than smaller plants. Also, the possibility of damaging roots and stolons increases as the plants increase in size, so there may be advantages to hilling when plants are younger and smaller (Carling *et al*., 2013).Proper management of the harvesting process reduces the number of tubers lost during the process, which not only results in a reduction of volunteer potatoes the following season, but also increases yields (Jamse and Allemann, 2013). The agronomic practices to ensure that the earthing up is sufficiently high so that all tubers will develop within the ridge help to minimise the number of tubers that are lost during harvest (Jamse and Allemann, 2013).

Therefore, earthing up needs to be applied as the potatoes grow. Earthing up is well be applied after planting soil will uniformly put around the plant up to 20 cm height and 15 cm top width at the different times of earthing up control (Tesfaye *et al*.,2012). Well keep a watchful eye for pest and disease control, paying attention to blight warnings will be of great assistance. Management practices such as weeding; cultivation, ridging will practice as per the recommendation (Gebremedihin *et al.,* 2008).

2.4.3.Soil temperate and moisture

Jamse and Allemann (2013) fluctuations in soil moisture status within the ridge will lead to uneven tuber bulking, malformed tubers and growth cracks. Even a 10% variation in soil moisture status can be critical. Growers in high temperature environments need to ensure quick canopy closure to minimize water loss due to evaporation from the soil surface. Potatoes produce a fibrous root system. As a result, potatoes are often unable to exploit nutrients and soil moisture at depth within a soil profile. While root growth occurs when soil temperatures are between 10 to̊C35 , best, most active root development is at soil temperatures of between 15 and 20˚C. Leaf (haulm) growth occurs at temperatures of between

7 to 30˚C, but optimal growth is at around 20 to 25˚C. Optimum temperatures for stolon grow this important.Tubers on top of the soil and up to 10 cm below the surface are killed by temperatures below -2°C, but the deeper tubers are insulated by the soil. The colder the soil temperature, the more rapid the initiation of tubers and the greater the number of tubers formed (Yara,2012). The optimum soil temperature for tuber initiation is 15 to 20˚C . Under these conditions, the potato plant will have short stolons and shoots. Once formed, tubers grow rapidly, reaching a maximum rate of up to 1400 kg/ha/day in temperate climates. Late varieties seem to be more sensitive to long day lengths or high temperature conditions (Yara, 2012**).**

As soon as the sprout breaks through the soil surface, leaves and branches starts forming on the nodes. The plant is now reliant on sunlight for photosynthesis and the underground sprouts starts forming stolons (Jamse and Allemann, 2013). During soil cultivation for the succeeding crop the soil is disturbed and tubers not damaged by this treatment will start to germinate and be well established by the time the follow-up crop is planted. Favorable weather conditions in terms moisture and temperature will enhance potato growth (Steiner *et al.,* 2005).Temperature also determines the length of the growing season (Ideally frost free but not too hot) and, as a consequence, the attainable yields. Day length determines tuber initiation. High temperatures tend to delay tuber initiation and stimulate haulm growth. Yield is determined by the amount of solar radiation the crop intercepts, so an early canopy closure increases production. Factors leading to early canopy closure include: higher plant densities, well pre-sprouted seed, planting depths that are not too deep, soil that is moist but not too cold, and a planting pattern where the distances between the rows are not too wide (NIVAA, 2002).

According to NIVAA, (2002) Water is vital importance to crops. It is indispensable for the most elementary processes such as photosynthesis and transport of minerals in plant and soil. only about 2% of the water needed by a crop is used for plant metabolic processes. The rest is transpired. The yield of a crop is determined to a large extent by the total amount of water that is available for the crop. With each liter of water transpired, the crop produces about 6 grams of dry matter. Good moisture during the various growth stages is essential for the production of quality tubers. The moisture just before or during tuber initiation (that is, approximately three weeks after emergence) is of vital importance. More water increases the number of tubers and their size. More soil moisture at tuber initiation also reduces the occurrence of common scab (NIVAA, 2002). The condition of the potato vines at harvest has been found to play an important role as both premature senescence of vines and green versus dead plants affect both the number of tubers that are left in the soil after harvest as well as the depth at which tubers are formed in the soil (Steiner *et al.*, 2005). Agronomic factors such as soil fertility and soil moisture management, as well as pest and disease control can contribute to premature vine senescence. Plants that senesce early produce a greater percentage of small tubers, and therefore more tubers will remain behind on the field at harvest, than those plants that mature later. When plants are still green at harvest, i.e. those plants that must be defoliated prior to harvest, produce more tubers that are also larger than those from plants harvested when dead (Jamse and Allemann, 2013).

2.5.Stemnumber

Admire *et al*.(2014) each stem from a single eye can be regarded as an independent production unit. Thus, a sufficient number of strong stems should develop per seed tuber. Investigations on stem density levels have also provided an insight on yield and quality of harvested tubers. A comprehensive understanding of this concept can be used to manipulate the production of ware and seed potatoes.Pavek and Thornton, (2009) and Svensson, (1962) suggested that longer stolons developing on short stems are most likely to expose the tuber to the soil surface leading to greening.The stem density of a potato crops is the number of stems per unit area and in production recommendations .The potato plant consists of various stem and each stem forms roots,stolen and tubers and behaves like an individual plant (Admire *et al*., 2014). However, as much as higher stem density results in greater yield, it also affects the size of tubers. Growth is limited when competition among steam is high. At higher stem density, the tuber produced remained smaller than at lower density, while the percentage of larger tubers decreased.Stem density is most likely to influence emergence of the potato crop and conversely, conditions that govern sprout emergence. There is however, no clear-cut position on how plants established at diverse densities have performed during the seedling emergence period (Admire *et al.*, 2014).

According to Admire *et al.*,(2014) each single main stem is regarded as a production unit, the yield of harvested tubers is most likely to vary with increase in stem numbers It is possible to get high tuber counts at low stem densities. Nevertheless, as much as higher stem densities result in greater yield that affect the size of tubers.Minimum competition for nutrient factors, space and exposure to adequate radiation interception adds to the potential for increasing tuber counts(Getachew *et al.*, 2012). Stem density is most likely to affect the quality of the harvested tubers in a way that might increase or decrease the economic value of the entire harvest attained. At higher stem densities, the tubers produced will smaller than at lower stem densities and the percentage of large tubers decreased (Gulluoglu and Arioglu, 2009).There is a greater possibility of obtaining a high number of green tubers at high stem densities since high stem population result in many tubers that compete for space within the ridge. The potato plant when exposed to direct sunlight develops a green pigment, which is caused by chlorophyll formation, and this renders the affected tuber unfit for marketing. In the presence of any process that leads to an accelerated rate of soil erosion on the surface of the ridge, the number of tubers exposed to direct sunlight and hence greening would increase. According Kouwenhoven, (2003) an increase in tuber volume that exceeds the soil volume surrounding the ridge led to tuber greening. Further, increased competition for nutrients and sunlight my result in shorter stems and hence, increased greening at high stem densities.

2.6. Tuber yield

Potato tuber is a function of both vegetative and reproductive growth, which occurs as a result of the interaction effect between the above and underground biomass the reproduction organ (Girma, 2001). The growth rate of a potato plant that is a well supplied with moisture and nutrient and free from pests and disease is nearly about proportional to its light absorption.

Yield can be determined by the fraction of total biomass that is partitioned to the tuber. Total biomass production and accumulation are dependent on the absorbed photo synthetically active radiation (PRA) that is directly proportional to the plant canopy cover (Spitters, 1987). According to Ronald (2005) provision of optimum growth condition could increase tuber yield, and the tuber increases was almost linear during the tuber bulking phase of development. The highest stem density increases leaf area early in the season and hence light interception and this in turn improve early tuber growth, but it may be countered balanced by increase in leaf senescence that reduces photosynthesis and slows tubers describes the proportion of tuber that is suitable for the end use. The primary and essential parameters in potato production is its fitness to the targeted purpose, in commercial terms, its marketability and obtaining the maximum yield consistent with the economy of production (Burton, 1989).

2.7. Marketable yield

At final harvest, the size distribution of the marketable yield represents only a fraction of the harvestable yields. This is because marketable yields exclude tubers with physiological disorders like second growth, growth cracks, damage and diseases (Struik *et al.*, 1990). In addition unmarketable small tubers are also removed from the size distribution According to Simeret *et al.* (2010) undersized (less than 20 g) were categorized as unmarketable.

Food industry demands for crisps or French fries potato cultivars having characteristic shape and size. The size distribution of harvested crop is one of the factors determining its economic value and specific grades are required for specific market outlets (Bekuma and van der Zaag, 1990). Most consumers require big size potatoes since large tubers are required for processing,while medium sized tubers are preferred for home consumption and the small once are oftenused by the farmers for seed and home consumption (Govinden, 2006). Potato tubers arecategorized into large, medium and small sizes, based on their size. Tubers less than 35 mmare considered small, those between 35-55mm are medium and greater than 55mm are largeand tubers which are healthy with a size more than or equal to 35 mm aregenerally consideredas marketable tuber (Hassanpanah *et al.*, 2009; Khan *et al.*, 2011; Abbas *et al.*, 2012).

3. MATERIALS AND METHODS

3.1. Description of the study area

The experiment was conducted at Eladale Research site Jimma University college of Agriculture and Veterinary Medicine, in the Jimma Zone Oromia Regional state during June 2014/15 cropping season. Jimma University College of Agriculture and Veterinary Medicine is geographically located 356 km southwest of Addis Ababa at about 7^o, 41^o N latitude and 36^o, 50^o E longitude at an altitude of 1710 m.a.s.l. Annual average rainfall of 1250 mm. The mean maximum and minimum temperature are 28^0C and 11^0C, respectively and the mean maximum and minimum relative humidity are 91.4% and 39.92% respectively(BPEDORS, 2000).

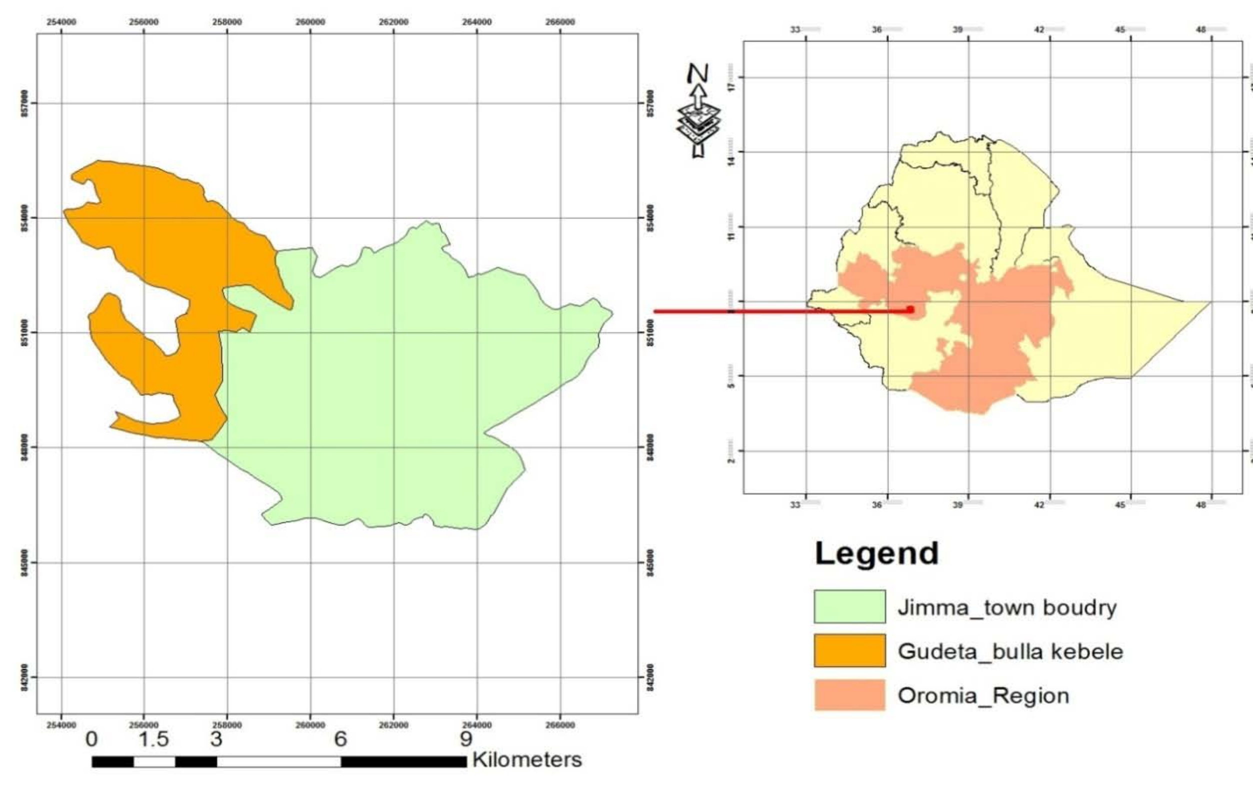

Figure 2**. Study site Gudeta Bulla Kebele**

Source: JTAO (2015)

3.2. Experimental Material

The potato variety named Jalane, which was developed and released by Holeta Agriculture Research center in 2002. The superior quality, disease resistant, commercial potato variety, Jalene was used in the experiment. It was sourced from Holleta Agricultural Research Center. Jalane variety adaptable in altitude of 1600-2800 m.a.sl and rainfall 750-1000mm .It is mature 90-120 day (HARC, 2004). The yield was on research field 44,800 and on-farm130 kilogram per hectare.

3.3. Experimental Treatments and Design

Two factors were considered. The first factor involved planting depth (10, 12 and 14cm). The the factor time of earthing-up were with four level (15 days, 30 days, 45 days after complete plant emergency and no earthing -up).For this factor time of earthing-up is based on the Tesfaye *et al.*, (20012) determined that earthing-up at 15 days after complete plant emergency accepted as standard.The experiment was laid out as a randomized complete block design in a 3X4 factorial arrangement and replicated three times. A plot size of 3 m by 3 m was used and adjacent plots and blocks were spaced 0.5 and 1 meter apart, respectively. Each of the eight treatment combinations was put on an experimental plot of (3m length x 3 m width).

Model

$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + €_{ijk}$

i = 1, 2…Depth of planting

j =1, 2…Time of earthing-up

k= 1, 2…Number of replication

Where, μ = The overall mean effects

y_{ijk} = The response measures for the ijk ^{the} observations

α_i = The effects of i^{the}planting depth

β_j = The effects of the j^{the}time of earthing-up

j = 1-4 , i = 1-3

$(\alpha\beta)_{ij}$ = The interaction effects between depth of planting and time of earthing-up

$€_{ijk}$ = The random error compared for the whole factor

k = Number of replication

Table 1. Detail treatment combination

Treatments	Planting Depth	Time of Earthing-up	Treatment combinations
1	Planting Depth10 cm(D1)	No Earthing-up (E0)	D1E0
2		Earthing- up after 15 day(E1)	D1E1
3		Earthing- up after 30day(E2)	D1E2
4		Earthing -up after 45 day(E3)	D1E3
1	Planting Depth12 cm(D2)	No Earthing-up (E0)	D2E0
2		Earthing -up after 15 day(E1)	D2E1
3		Earthing -up after 30day(E2)	D2E2
4		Earthing- up after 45 day(E3)	D2E3
1	Planting Depth14 cm(D3)	No Earthing-up (E0)	D3E0
2		Earthing -up after 15 day(E1)	D3E1
3		Earthing -up after 30day(E2)	D3E2
4		Earthing -up after 45 day(E3)	D3E3

3.4. Experimental Procedures

The land was ploughed four times by oxen plough according to farmers' practice. The whole field was divided into three blocks each containing 12 plots. The size of each unit plot was (3m length x 3 m width), having plant-to-plant and row-to-row spacing 0.3m and 0.75m, respectively. The tuber size, 35-45 mm in diameter for all treatment (HARC, 2004). A distance of 0.5m and 1m was maintained between unit plot and blocks respectively. Each plot had 4 rows.Earthing-up was done uniformly by hilling the soil around the plant up to 20 cm height and 15 cm top width according to the time of earthing-up given for each treatment except the control (Tesfaye *et al.*, 2012). The seed potato was obtained from Holeta Agriculture Research center.Potato tubers were hand plant and planting depth was maintaining around 10 cm, 12 cm and 14 cm. Phosphorus was applied in the form of DAP during planting time at the rate of 195 kg per hectare and nitrogen was also applied in the form of UREA in a split, first during planting and then side dressed after full emergence at a rate of 165 kg per hectare(HARC, 2004), other management practice was used uniformly for all treatments based on recommendation.

3.5. Data collection and analysis

3.5.1. Growth parameters

Parameters including days to emergence, number of main stems, flowering and plant height, maturity and plant spread was recorded to evaluate the effect time of earthing-up and planting depth on yield and yield components of potato.

1. **Days to 50% emergence: -** Days to 50% emergence was record by counting the number of days from the date of planting to the date at which about 50% of the plants in a plot Emerge out.

2. **Days to 50% flowering:-** Days to flowering was record by counting the number of Days, in which 4 plants flowered out of 8 plants per each treatment.

3. **Days to 50% maturity; -** Days to maturity was record when the haulms (vines) of 50% of the plant population have yellowed by counting the number of days, in which 4 plants maturity out of 8 plants per each treatment.

4. **Main Number of stems per hill: -** The actual number of stem per plant was recorded by counting the main stem; that came out from the seed tuber.

5. **Plant height (cm):** Plant height was determined by measuring the height of the plant from the base of the main shoot to the apex at full blooming stage.

6. **Plant Spread (cm):-** Plant spread was determined by measuring the length canopy from the base of the main shoot to the apex at full blooming stage of plant.

3.5.2. Yield parameters

Parameters such as number of tubers per plant, average tuber weight, marketable tuber yield, unmarketable tuber yield and total tuber yield was measured to assess the effect time of earthing-up and planting depth on yield and yield components of potato.

1. **Total number of tuber (count/hill): –** The average number of total tubers per hill from middle hills of central rows (8 hills) was taken.

2. **Average tuber weight (g): –** It was recorded by dividing total fresh weight of tubers per plot by the total number of tubers.

3. **Marketable tuber yield (t ha^{-1}): -** At harvesting eight plants were taken from each plot healthy tubers with a size equal or more than 35 mm in diameter were taken as marketable.

4. **Unmarketable tuber yield (t ha^{-1}): -** Rotten, diseased, insect attacked, deformed tuber and Small size was weight.

5. **Tuber yield (t ha^{-1}):-** It was recorded by the sum of both marketable and unmarketable tuber yields.

3.5.3. Quality parameters

1. **No. of green tubers**; Number of green tuber per plant was counted per hill.

3.5.4 Data analysis

The data was collectper plot basis checked for meeting all the ANOVA assumptions and subjected to analysis of variance Randomized Complete Block Design (RCBD) of SAS Version 9.2 statistical software (SAS Institute Inc., 2002). Treatment means was separate by using LSD value at 5% significance level and correlation analyses among studied parameters were also performed.

4. RESULTS AND DISCUSSION

4.1. Growth Parameters

The results of the current investigation obtained in terms of growth parameters including days to50% emergence, days to 50% flowering, days to 50% maturity, main stem number/hill, plant height and plantspread are presented (Table 2, 3, 5 and6).

4.1.1. Days to 50% emergence

Planting depth highly significantly ($P< 0.01$) influenced the number of days taken for the crop to emerge. However, time of earthing-up and the interaction effects of both factor was no significant ($p>0.05$) for plant emergence (Appendix Table 6).Increasing the planting depth of 10 cm to 14 cm potato increased the number of days from sowing to emergence. The earliest days to 50% emergence was recorded at 10 cm planting depth (12.54) days. Whereas, days to 50 % emergence was prolonged in 14 cm planting depths (16.98) days (Table 2). The fact that emergence was typically delayed as planting depth increased due to temperature variability across the field and soil depth (Pavek and Thornton,2009). The difference soil depths are difference soil temperature that delay or hasten the emergency.The results are also in agreement with findings of Sultana *et al.*(2001) who verified that, Plant emergence was occasionally delayed with an increase in planting depth. The potato sprouts had to come across a long distance of the ground to emergence than the shallow planting. Abdulla *et al.* (1993) percentages of plant emergence were affected by planting depth. Time of earthing-up after of full emergency there is no relationship with emergence sprouts develop from eyes on seed tubers and grow upward to emerge from the soil, roots begin to develop at the base of emerging sprouts, and the seed piece is the sole energy source for growth during this stage (Adersn and Cliston, 2010).

Table 2. Effect of planting depth on days to 50% emergence

Treatments	Days to 50% emergence
Planting Depth (cm)	
10	12.54[c]
12	15.35[b]
14	16.98[a]
LSD (5%)	1.87
CV (%)	8.10

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

4.1.2. Days to 50% flowering

Days to 50 % flowering was highly and significantly ($P<0.01$) affected by planting depth and time of earthing-up. However, no significant ($P>0.05$) interaction effect was observed between planting depth and time of earthing-up on days to 50 % flowering (Appendix Table 9). The prolonged days to 50% flowering was observed at optimum planting depth of 12cm. whereas, days to 50% flowering was earliest in 10 and 14 cm planting depth (Table 5). However, Planting depth 10 and 14cm was statistically similar took to reach its 50% flowering. May be due to shallow planting depth that lead the plants to stress and ultimately the plants flower early instead of prolonged the growth. The soil moisture at 10 cm affected by maximum temperature that lead vaporization (Fernando *et al.*, 2006). This result agreement to (Almekinders and Struik, 1996; Sleper and Poehlman, 2006) indicated that let flowering in potato when abundant moisture, and cool temperatures. Similar result showed by Adersn and Cliston (2010) this is may be due to unfavorable condition for potato growth that cause the difference soil moisture, aeration and temperature prolonged the date of flowering. Also Jane *et al.* (2014) indicated thatwhen un optimum soil depth that lead problem of soil temperature, soil moisture and soil air this cause stolen low tuber formation and small number of steam with vigor’s growth finally lead early flowering.

Days to 50% flowering was significantly delayed at time of 15 days of earthing- up. At time of 15 days after full plant emergence of earthing- up delayed flowering by 5 days than no earthing-up.No earthing-up (control) was none significant difference from earthing-up at 45 days after full plant emergence (61 and 62.45) respectably. In general, the number of days to flowering was significantly decreased as period of earthing-up no earthing-up. However, this result is agreement to Tesfaye *et al.* (2012) this is due to flowering was prolonged when potatoes was earthed-up at 15 days after complete plant emergence, absence of earthing-up created stress on the plant due to lack of aeration and mechanical barrier of soil colloids during its active growth stage that affected the plant growth and brought early flowering. This early flowering is also related with days to emergence; potatoes which emerged earlier did also flower earlier than those emerged later. The physiological condition of potato seed tuber affects emergence and growth of potato crop (Wiersema, 1999).

4.1.3. Days to 50% maturity

Days to 50% maturity was highly and significantly ($P<0.01$) affected by both planting depth and time of earthing -up. This parameter was also significantly ($P< 0.01$) affected by the interaction of the two factors(Appendix Table 10). The vegetation period for potato varied from 112.58 to 116.05 days depending planting depth and time of earthing -up. The longest days to maturity was recorded from 12 cm planting depth with at 15 days earthing up after full emergency while the planting depth combination with time of earthin-up 10cm x 0cm, and 10cm x 45 were recorded (112.58,113.38) respectively matured early (Table 3).Agreement with the finding of Tesfaye *et al.* (2012) that earthing-up at 15 days after complete plant emergency, matching with the active growth stage of the plant, created favorable soil environment and enhanced further vegetative growth that extended days to maturity. The correct choice of time of earthing-up iscritical as far as crop yields and quality achievement are concerned.Soil temperatures play a major role in determining the length the off season that is related to depth of planting in the soil.

Table3. Day to 50% maturity of potato as affected by the interaction depth of planting and time of earting-up

Depth of Planting(cm)	Days to 50 % maturity			
	Time of earthing-up(days)			
	0	15	30	45
10	112.58[i]	115.30[cde]	114.08[gh]	113.38[hi]
12	115.00[def]	117.21[a]	116.45[b]	115.30[cde]
14	113.61[gh]	116.05[bc]	114.75[efg]	114.17[fgh]
LSD (5%)	0.87			
CV (%)	10.07			

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

4.1.4. Number of main stems per plant

Number of main stems per hill was highly and significantly (P<0.01) affected by depth of planting and time of earthing-up. However, the interaction effect between depth of planting and time of earthing-up was found to be non-significant (Appendix Table 7). The highest number of main stems was 3.90 recorded at depth at 12cmdepthplantingthis value was statistically significant with main stem numbers obtained from both planting depth at 10 and 14, (Table 5).Production of higher main stem number per hill by planting depth at 12 cm was probably due to at 12 cm planting depth might have resulted from favorable environmental condition like soil moisture ,temperature, free from soil born disease and soil air and healthier plants. Hanbar *et al.* (2012) the number of stems per plant decreased with increased planting depth. The experiment conducted by Hamidreza *et al.* (2011) indicated that larger number of stems at 20 cm depth compared to 30 cm. Pavek and Thornton (2009) studies further strengthen the argument that the effects of planting depth on stem and stolon growth appear to be cultivar dependent.Iritani *et al*. (1983) produce more stems when planted into closer to the soil surface. The smaller the tuber and the deeper it is buried in the soil, the smaller the chance that the stem will emerge (James and Allemann, 2013). Throughout emergence and stolon development the shallowest planted seed pieces were exposed to warmer average soil temperatures than those planted deeper. As it can be seen maximum depth of was cut, the reason is that with increased planting depth has decreased the number of stem (Hanbar *et al.*, 2013).

Earthing-up at 15 days maximum main stem number per hill 4.06, while the lowest number of main stems was recorded for earthing-up at 45 days after full emergence (3.04) on average per plant and this value was statistically not significant with main stem numbers obtained from no erthing-up (3.09). Agreement with the result of Tesfaye *et al.* (2012) reported that cultural practice, given to the plant during active growth stage, enhanced the growth and development to plant stem. This result confirm with Majid and Roza (2001) reported that the soiling in the height of 15 cm, because the plants are not growing well, so could not properly use the environmental resources and for this reason the number of stems per tuber was reduced. However, when the plant height was 25 to 35 cm, the soiling with controlling the vegetative growth and encouraging the underground growth (or development) cause to inhibition of longitudinal growth and will increase the number of stems. Strongly agree to Muhammad *et al.* (2013) the minimum number of stems per plant (1.9) was recorded in plants planted haphazard on un leveled land, followed by tubers when planted in furrows without ridges. Potato planted on plain wide beds and covered from one side gave maximum number of stems per plant (3.5). It may be due to aeration and earthing-up that were provided to the tubers in this planting system. This parameter is of great importance because it is directly related with the total production of tubers.

4.1.5. Plant height

Plant height was highly and significantly ($P<0.01$) affected by depth of planting and time of earthing-up. However, the interaction between depth of planting and time of earthing-up was not significant ($P>0.05$). The depth of planting at 12 cm had significantly the tallest (61.24 cm) plant height, while depth of planting at 10 cm (56.46 cm) was the shortest (Table 5). Recorded plant height of depth of planting at 12 cm was higher by 4.78cm and 2.26cm than depth of planting at 10 cm and 14 cm, respectively. Sultan *et al.*(2001) reported that plant height at maximum vegetative growth stage, plant height obtained from 7.5cm depth of planting were found maximum and the lowest height was recorded from surface planting.

This indicate when planting the near to the surface the plant height is decreased relatively similar trend was observed in this study. In the other case Abbasifar *et al.*(1995) reported that plant height was shortened as planting depth was increased.

On the other hand, earthing-up at different days after full plant emergence resulted to difference in plant height. significantly the tallest plant height (61.46cm) was recorded at earthing-up at 15 days after full emergence followed by the earthing-up at 30 days after full emergence (59.67cm), while the shortest (54.46cm) from the delayed earthin-up at earthing-up at 45 days after full emergence and this value was statistically not significant with planting at no earthing-up. Earthing-up at 15 days after full emergence increased plant height by 7cm compare to that at earthing-up at 45 days after full emergence. Generally, as earthing-up delayed reduction on plant height was observed especially at 45 days of earthing-up. This might be due to moisture and nutrient use efficiency at late earthing potatoes. Agreement with the result of Tesfaye *et al.* (2012) that early soil cultivation (earthing-up) facilitated the nutrient absorption though enhanced microbial processes and increased soil aeration.

4.1.6. Plant spread

Plant spread was highly and significantly ($P<0.01$) affected by both planting depth and time of earthing-up. This parameter was also significantly ($P< 0.05$) affected by the interaction of planting depth and time of earthing-up. The plant spread for potato varied from 35.79 to 50.40 cm depending to planting depth used and time of earthing-up (Appendix Table 11). The higher to plant spread was recorded from planting depth 12cm from all earthing-up treatment ,however the higher was recorded at time of earthing-up at 15 days after full emergence while the shallow planted 10 cm with at no earthing-up (Table 4). No earthing-up was practiced in this method, therefore some plants fill down due to less support and bare roots on soil surface. This result line with the study of Tesfaye *et al.* (2012) is significantly the widest plant spread was observed earthing-up at 15 days after full plant emergency. This could be due to the reason that earthing-up at 15 days after complete plant emergency early in the growing season of the potato plant coincide with the proper time of soil workability and optimum soil moisture level. This made the soil porous, aerated and the plant receive the advantaged of proper growth and development than the plant on the control and lately managed plots.

Atshallow planting, the length of plant spread decreased in all tested time of earthing-up. One reason may be due to earthing-up, which provided enough nutrients in the roots zone of the plants and also due to the favorable environment this method provided to the plants leading to good emergence and healthier plants.

Table 4 .Plant spread of potato as affected by the interaction depth of planting and time of earthing-up

Depth of Planting (cm)	Plant spread			
	Time of earthing-up(days)			
	0	15	30	45
10	35.79^{i}	42.55^{ef}	39.98^{g}	38.00^{h}
12	46.33^{c}	50.40^{a}	48.36^{b}	47.37^{bc}
14	41.53^{f}	46.61^{c}	44.04^{d}	43.36^{de}
LSD (5%)	1.47			
CV (%)	1.13			

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

Table 5. Effect of planting depth and time of earthing-up on main stem number/hill, days to 50% flowering and plant height

Treatments	Main Steam Number /Hill	Days to 50% Flowering	Plant Height(cm)
Planting Depth (cm)			
10	3.11[b]	62.14[b]	56.46[c]
12	3.90[a]	65.62[a]	61.24[a]
14	3.16[b]	62.84[b]	58.98[b]
LSD (5%)	0.35	1.61	0.50
Time of earthing-up after Full emergence (Days)			
0	3.09[b]	61.39[c]	56.97[c]
15	4.06[a]	66.17[a]	61.46[a]
30	3.38[b]	64.11[b]	59.67[b]
45	3.04[b]	62.45[bc]	54.46[c]
LSD (5%)	0.41	1.85	0.58
CV (%)	12.81	2.95	1.07

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

4.2. Yield Parameters

This experiment results obtained yield parameters such as number of tubers per plant, marketable tuber yield, unmarketable tuber yield, total tuber yield, average tuber weight and number of green tuber are presented (Table 6, 7 and 8)

4.2.1. Total number of tubers

Total tuber number count per hill was highly and significantly ($P<0.01$) planting depth and time of earthing-up. This parameter was also significantly ($P<0.01$) affected by the interaction of depth of planting and time of earthing-up in table 7 Appendix table 5. Total tuber number count per hill varied from 6.75 to 10.13 numbers depending to planting depth and time of earthing-up. At 12cm depth constantly higher numbers of tubers were recorded for all time of earthing-up. However, the large number of total tuber number count per hill was recorded from at time of earthing-up at 15 days of after full complete plant emergency combined with planting depth at 10 cm and 12 were recorded (9.52 and 10.13), respectively. While, the minimum number of total tuber number count per hill was recorded from no earthing-up combined with planting depth at 10cm observed 7.52, this is statically none significant to time of earthing-up 45 days after full complete plant emergency combine with depth of planting at 10 cm and 14cm (7.78 and 8.32) ,respectively (Table 6).

This result agrees with that Gholipour (1996) who reported that number of produced tubers per plant and unit area decreased as planting depth increased and mentioned the reduction of stem number. Agreement to the result of Adersn and Cliston (2010) tuber initiation is slower at temperatures over 20^{o}C. The optimum soil temperature for initiating tubers ranges from 16 to 19°C .Under high soil temperatures, stolonization was substantially compromised and there was no underground tuber development. Tuber development declines as soil temperatures rise above 20°C and tuber growth practically stops at soil temperatures above 30°C. The number of tubers set per plant is greater at lower temperatures than at higher temperatures. May be due, to soil depth difference, increased duration of water stress before tuber initiation reduces tuber set per stem.

AlsoKrystyna (2013) that soil moisture favorable for plants led to an increase of the number of tubers. The stolon number are affected the tuber number formed. Agreement to Darwin

(1991) result showed that planting depth had an effect on the stolon length and the stolon position and hence on the position of the tuber in the soil. The stolon length varied with the planting depth and with deeper planting the stolons was very short. The stolon numbers affected at 0 cm, very few stolons formed tubers. Due to this reason number of tuber decrease in the shallow planting depth.

Covering nodes by hilling stiroulated the rate of stolon formation during active growth stage of the plant. This study lined with Harder *et al*. (2013) that totally planting depth and method of farming, soil temperature and humidity around the tubers grown has significant effect in this regard, the planting depth and soil conditions should be set. This result is also similar to Lorenz(1945) that, the number of tubers per hill became smaller as the depth of planting was increased. Time of earthing-up significantly affect the tuber number due to the critical active stage of the growth and development of potato favorable soil conditions in terms of soil moisture and temperature enhance plant growth.

Agreement to Tafi *et al.* (2010) adding soil increase tuber numbers per bush .The root system develops rapidly during early growth and thereafter, root length, density, and root mass decrease as the plant matures. Leaves and branches develop on emerged sprouts; roots and stolons develop below ground, and photosynthesis begins. Potato development in stages lasts from 30 to 70 days, depending on planting date, physiological age of the seed tubers, cultivar, soil temperature, and other environmental factors. Adersn and Cliston (2010) may be due to this reason early stage earthing-up can create favorable condition for potato large number of tuber formation.The colder the soil temperature, the more rapid the initiation of tubers and the greater the number of tubers formed.

The optimum soil temperature for tuber initiation is 59 to 68˚F (15 to 20˚C).May be due to active growth stage of plant and favorable environment condition. This work line with Majid and Roza (2011) that, according to the number of tubers per unit area, the effects of time and depth of soling the plant foot has had a significant effect. So, that when the plant height reached 25 or 35 cm the maximum number of tubers per unit area. Due to the plant’s severe need of the soil moisture and nutrients at this stage, and soil are forming, food and moisture around the plants accommodated is with less evaporation, thus, creates a suitable environment for growth of rhizomes.

Table 6.Total tuber number of potato as affected by the interaction depth of planting and time of Earthing-up

Depth of Planting (cm)	Total tuber number			
	Time of earthing-up (days)			
	0	15	30	45
10	7.52^{f}	9.52^{ab}	8.81^{cd}	7.78^{ef}
12	8.78^{cd}	10.13^{a}	9.00^{bc}	8.32^{de}
14	6.75^{g}	9.17^{bc}	8.60^{cd}	7.51^{f}
LSD (5%)	0.64			
CV (%)	3.70			

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

4.2.2. Total tuber yield

Total tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Appendix Table 4). The maximum total tuber yield was recorded (26.72) at depth of planting 12cm while, at planting depth 10 and 14 cm statically none significant. Mean comparison of different planting depths indicates that 12 cm depth possessed greater yield in comparison with 10 and 14 cm depths (Table 8). Findings of this research revealed that larger number of stem at 12 cm depth compared to that of 10 cm depth would result in exceeding competition for environmental factors among crops. On the other hand, this situation improves crop capability of producing photosynthetic matters and increases every tuber's portion from the photosynthetic products (Hamid *et al.*, 2011). Pavek and Thornton (2009) under high soil temperatures, stolonization was substantially compromised and there was no underground tuber development. The induction of tuberization by the leaves was affected mainly by air rather than soil temperature, but the signal to tuberize might be blocked by high soil temperatures Adersn and Cliston (2010). This result is in line with the finding of Mahmood *et al.* (2002) reported that mulch at Islamabad, Pakistan, decreased daily maximum soil temperature at a 15 cm-depth by 1.5 to 4.5^{o}C, resulting in faster emergence, earlier canopy development, and higher tuber yields. Stalham *et al.* (2005)

reported that, potato crops planted into soil with a resistance greater than the threshold for root penetration will develop shallow, restricted rooting systems with a limited capacity for exploiting reserves of water and nutrients in the soil. Water uptake in such crops will almost certainly be limited and, as a consequence, canopy growth, light interception, water use and ultimately yield will be reduced. The result is consistent with Hanbar *et al*. (2013) who reported that proper planting depth to be usually the most important factor to achieve maximum product performance

With regard to time of earthing-up the maximum total tuber yield was recorded (28.28) earthing-up at 15 days of after complete plant emergency while, minimum total tuber yield recorded at no earthing-up (21.94)and earthing-up at 45 days of after complete plant emergency(22.64)statically none significant (Table 8). This result is line with the study of Tafi *et al*. (2010) the mutual effect of the soil adding is significant from the yield characteristic view, which it indicates the varieties different reaction toward the appropriate time of the soil adding from the limits of philological growth stages view. That adding soil could increase tuber yield significantly compared to non adding soil which led to improvement of total yield. Don and James, (199) all hilled treatments yielded significantly more than the treatment that was not hilled. This work line with Majid and Roza (2011)time and depth of soiling of the plant foot had a significant effect on the percentage of potato yield per unit area. So, that when the plant height reached 25 or 35 cm the maximum number of tubers per unit area. Due to the plant's severe need of the soil moisture and nutrients at this stage, and soil are forming, food and moisture around the plants collected is with less evaporation, thus, creates a suitable environment for growth of rhizomes.

4.2.3. Marketable tuber yield

Marketable tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Appendix Table 3). Higher marketable yield was registered by planting depth at 12 cm, while the minimum marketable yield was produced by planting depth at 10 cm (17.23) and 14 cm (17.77) this are statically none significant. Planting depth at 12 cm showed maximum marketable tuber yield by 38.82% as compared to planting depth at 10 cm (Table 8). The marketable yield reduction was presumably due to an increase in green tuber yield at the shallow planting depth. The result was agreement with Pavek and Thornton(2009) result show that marketable yield and gross income typically declined when seed pieces were planted shallow (10 cm). The largest impact to marketable yield and gross income came from green tubers. Tuber greening was reduced as seed pieces were planted deeper. Multiple studies indicate that green or sunburned tuber yield can be significantly reduced by increasing planting depth. Infected with Phytophthora infestans as the season progresses (Lacey, 1966). Deeper planting depths may include marketable yield reduction a likely increase in soil volume that harvesters would have to lift. Pavek and Thornton (2009) shallow planting depth include reduced early-season moisture to plants and occasionally, lower marketable yields due to an increase in undersized, green, and surface-exposed tubers. Intermediate depth planting was critical for higher marketable tuber. This result indicate that tubers were set at intermediate depth in the soil is very important that increase the performance of potato. Planting deeper appears unnecessary and it may increase the risk of disease and seed piece rot from delayed emergence during colder years.

Time of earthing-up recorded, recorded marketable tuber yield from plots planted on earthing-up at 15 days after full emergence was maximum by 38.82% and 34.6 % than marketable tuber yield from plots planted no earthing-up and earthing-up at 45 days after full emergence, respectively. No earthing-up and earthing-up at 45 days after full emergence are statically none significant. Results of this experiment revealed that no earthing-up and delaying of earthing-up at resulted in higher percentage of rotten, disease, insect attacked, deformend tubes , as a result of which high unmarketable tuber number.

Moreover, the seed potato is surrounded by soil of a high moisture content, a necessary condition for sprout and root growth. The favorable results obtained when earthing-up early, may be caused by higher moisture content in the ridge and a part of the subsoil brought about by a reduction of the number of cultivations (Kouwenhoven, 1970). Similarly, agreement with the work of Tesfaye *et al*. (2012) result showed that this could be due to plant improved the soil conditions for proper root growth and nutrient absorption that facilitate the above ground part for better growth and development ultimately resulted for the better marketable tuber yield. At the right time of earthing-up can produce condition for the plant that was good aeration, moisture movement, and soil condition to absorb nutrient and water during in this active growth stage.

4.2.4. Unmarketable tuber yield

Unmarketable tuber yield was highly significant at ($P < 0.01$) affected by planting depth and time of earthing-up, however interaction effect between planting depth and time of earthing-up was none significant ($P>0.05$) (Appendix Table 2). Higher non-marketable yield was registered by planting depth at 10 cm, while the minimum non-marketable yield was produced by planting depth at 12 cm. planting depth at 12 cm and planting depth at 14 cm showed reduced unmarketable tuber yield by 37.07% and 17.86 %, respectively as compared to planting depth at 10 cm (Table 8). Tubers in the field exposed to sunlight through cracks in the soil or protruding from the trill that turn green before harvest and increase in undersized are graded out as unmarketable(William and Stephen, 2005).

Porter *et al*.(2005) the result was show the incidence of infection of tubers at the soil surface was 54% when all surface tubers were combined over all experiments. Sunburned or green tubers harvested from fields with late blight during the growing season are high-risk tubers due to their surface location. Tubers located deep in the soil are better protected from infection than surface or shallow tubers. Tuber infection decreased with increasing soil depth in all soils tested. Concentrations of sporangia and zoospores are reduced at greater soil depths due to the filtering capabilities of the soil. The pore size in soil decreases as the moisture level increases, but increased soil moisture provides a continuous water medium which benefits the movement of sporangia and zoospores through soil. Similarly, Nyankanga *et al.* (2008) studies have shown that movement of fungal propagules is influenced by soil moisture, soil type and soil temperature. Stem number and plant height can strongly influence non-marketable yield of many potato cultivars (Arsenault and Christie, 2004).

Adersn and Cliston (2010) result show that in unproper soil depth that cause deficiency soil moisture increase the attack of cutworms and mites. Low soil moisture also increases formation of cracks in the soil, which allow the entry of potato tubermoth and its larvae. The misshaped tuber formed due to soil depth temperature difference. The result was agreement with Krystyna (2013) high temperatures during early stages of tuber development caused lower the percentage of misshapen tubers.

Soil moisture favorable for plant growth in the first periods of heat stress was significantly more conducive to the physiological defects of tubers the soil moisture difference due to soil depth difference related to temperature cause of physiological disorder of tuber. Similarly, Selman *et al*. (2008) reported that growth cracks and secondary growth tuber cracking occurs when the potato splits while still growing. These cracks generally start at the bud or apical end of the potato and extend lengthwise secondary growth refers to knobs that grow from lateral buds the cause: Both of these physiological problems are related to fluctuations in soil moisture and rapid, uneven uptake of water. This is the same the result of Majid and Roza (2011), result show that, the largest impact to marketable yield and gross income came from green tubers. Planting deeper appears unnecessary and it may increase the risk of disease and seed piece rot from delayed emergence during colder years (Pavek and Thornton, 2009).

With regard to time of earthing-up, recorded unmarketable tuber yield from plots planted on earthing-up at 15 days after full emergence was lower by 16.55% and 10.65 % than unmarketable tuber yield from plots planted earthing-up at 45 and 30 days after full emergence respectively. Treatment no earthing-up and at 45 days of after full emergency statically none significant (Table 8). Results of this experiment revealed that the delaying earthing-up and no earthing-up resulted in higher percentage of green tuber deformed disease attacked and small sized tubers as a result of which high unmarketable tuber number. Moreover, higher number of affected tubers by disease, size, malformed and tubers green color and pre-harvest sprouting on tubers was observed in no earthing-up and late of earthing-up. This work agreement with Tafi *et al*. (2010) reported that soil adding to the bush affects on the potato product structure. This is due to appropriate time of the soil adding for active physiological growth stages that create favorable soil environment for that plant growth and development plant. Hilling can be an effective late blight management strategy as long as intact soil is present over the surface of the tubers (Arsenault and Christie, 2004).

4.2.5. Average tuber weight

The results pertaining to average tuber weight per hill statistically displayed highly significant ($P<0.01$) difference among potato planting depth and time of earthing-up (Appendix Table 1). On the other hand, the interaction effect of planting depth and time of earthing-up was found to be not significantly ($P>0.05$). Average tuber weight at shallow planting depth was (43.91) lower by 9.29% (47.40) and 8.37 % (47.07) than average tuber weight per at 12 cm and 14 cm depth of planting respectively. Planted 12 cm and 14 cm depth of were statically none significant (Table 8). Hanbar *et al.*(2013)increased number of stem gland may also increase the number tuber, because the production of seed tubers, the tuber is the weight of the gland.May be the depth is greater total gland weight less but increased. But what he under line that as it can be seen maximum depth of was cut the reason is that with increased planting depth has decreased the number of stem and reducing the number of stem tuber is reduced thus reducing the number of gland function is decreased. The deeper planted potatoes had higher average tuber weights than those planted shallow.

With regard to time of earthing-up average tuber weights per hill planted on earthing-up at 15 days and 30 days after full emergence was maximum (48.78g) and (46.98g) than average tuber weights per hill planted no earthing-up and earthing-up at 45 days after full emergence (44.23g) and (44.52g) respectively (Table 8). No Earthing-up and earthing-up at 45 days after full emergence are statically none significant. Results of this experiment revealed that the no earthing-up and delaying of earthing-up resulted in lower average tuber weights per hill.The result was line with Tafi *et al*. (2010) show that soil adding significant average tuber weight the potential average tuber weight that can be successfully produced by time of earthing-up with the tuber numbers per bush, tuber yield, number of stems per hill (stem population) and environmental conditions during the initiation phase of growth.

4.2.6. Number of green tuber

The number of green tuber was highly and significantly (P<0.01) planting depth and time of earthing-up. This parameter was also significantly (P<0.01) affected by the interaction of depth of planting and time of earthing-up (Appendix table 12). In the local agro-ecological condition of jimma, the number of green tuber potato varied from 0.63 to 2.88 depending to planting depth and time of earthing-up. The large number of number of green tuber potato was recorded from no earthing-up with planting depth at 10cm, 12cm and 14cm was (2.88, 2.36 and 2.11) respectively, while time of earthing-up after full emergency with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and 45days x14cm) were recorded the lowest number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively (Table 7). The lowest number of green tuber per hill on deep planting was probably due to the deep planting potato its, very low chance to exposed to sun light and the large volume of soil hilling effect that protect potato from expose direct sun light. Numbers of green tuber depend on time and condition of earthing-up. Early earthing-up is important, during potato growth in the first active growth tuber initiation stage and required timely earthing-up. After tubers changed to green tuber, late earthing-up potato there is no chance to change the original pigment (potato once it can be developed the toxic Compound).

ResultSelman *et al.* (2008) and Majid and Roza (2011) result show that, potato tuber exposure to light in the field causes the formation of a green pigmentation on the potato. This occurs when sunlight directly contacts tubers growing at or near the soil surface or reaches tubers through cracks in the soil surface. This result is line with that of Pavek and Thornton (2009) who reportedthat during harvest when some tubers displayed a well defined green strip across their surface which presumably came from a sunlight-saturated soil crack. Additionally, the longer stolons found on stems of the shallowest-planted seed pieces may have exacerbated tuber greening by positioning tubers nearer the sides of the hill. No single planting depth will optimize grower revenue across all situations. Potatoes should be planted deep enough to avoid tuber greening, surface-exposed tubers, soil moisture deficits, and to accommodate the predicted yield.

Similarly, William and Stephen (2005) noted that think that planting seed pieces deeper should help to minimize tubers growing out of the top of a hill, thus reducing field tuber greening. The Highest number of green tubers was observed for the shallow planting depth for no earthing-up used in the experiment. Number of green tubers are increased only when the chance of tubers exposed to direct sun light as decrease the depth of planting and no earthing-up, Agreement with the work of Don and Games (1990) maximum number of green tuber under no hilling.However, produced many green tubers when plants were not hilled, significantly more than any of the hilled treatments. The results coincide with the findings of Muhammad*et al.* (2013) who reported that ridging significantly improved yield and reduced tuber greening.

Table 7 .Number of green tuber of potato as affected by the interaction depth of planting and time of earthing-up

Depth of Planting (cm)	Number of green tuber			
	Time of earthing-up (days)			
	0	15	30	45
10	2.88^{a}	1.48^{bcde}	1.65^{bcd}	1.98^{abcd}
12	2.36^{ab}	1.16^{cde}	1.23^{cde}	1.73^{bcd}
14	2.11^{abc}	0.63^{e}	1^{de}	1.56^{bcde}
LSD (5%)	0.98			
CV (%)	4.66			

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

Table 8 .Effect of planting depth and time of earthing-up on unmarketable tuber yield (ton/ha) marketable tuber yield (ton/ha), average tuber weight (g)

Treatments	Unmarketable Tuber yield (ton/ha)	Marketable Tuber Yield, (ton/ha)	Total Tuber Yield (ton/ha)	Average Tuber Weight (g)
Planting Depth (cm)				
10	4.99[a]	18.69[b]	23.68[b]	43.91[b]
12	3.14[c]	23.57[a]	26.72[a]	47.40[a]
14	4.10[b]	19.62[b]	23.72[b]	47.07[a]
LSD (5%)	0.15	1.29	1.28	1.47
Time of Earthing-up After Full emergence (Days)				
0	4.26[a]	17.23[c]	21.94[c]	44.23[c]
15	3.68[c]	23.92[a]	28.28[a]	48.78[a]
30	3.94[b]	21.26[b]	25.99[b]	46.98[b]
45	4.41[a]	17.77[c]	22.64[c]	44.52[c]
LSD (5%)	0.18	1.47	1.47	1.70
CV (%)	4.28	7.04	5.83	3.88

LSD = Least Significant Difference; CV = Coefficient of Variation; Values following by the same letter within the column or row are not significantly different at 0.05 probability level

4.3. Correlation analysis among yield and yield component parameters

The result of correlation analysis showed that (Table12) total tuber number per plant (r = 0.766), average tuber weight (r = 0.577), marketable tuber yield (r =0.975), steam number (r = 0.798), plant height (r = 0.789), day of flowering (r= 0.564), days of maturity (r=761) and plant spread (r=0.648) correlated significantly and positively (P<0.01) with total tuber yield. These result showed that any positive increase in such characters had boasted total tuber yield (Table 12). On the other hand, negative and significant (P<0.01) correlations were determined in the unmarketable yield (r = -0.508) and number of green tuber (r = -0.520).

Plant characters also showed significant association with one another. Marketable tuber yield associated positively and significantly (P<0.01) with average tuber weight (r = 0.642), total tuber number (0.784), steam number (r=0.784), plant height (r=0.873), days to flowering (r = 0.656), days of maturity (r=0.847), and plant spread (r = 0.759). Main stem number associated positively and significantly with marketable tuber yield (r = 0.808, P<0.01). Unmarketable tuberyield (r = -0.522) and number of green tuber (r = -0.418) were negatively correlated with main stem number at (P<0.01) and (p<0.05), respectively. Unmarketable tuber yield negative and highly significant (P<0.01) correlation between main stem number (r = -0.522), plant height (r = -0.803) and total tuber number (r = -0.534,), total tuber Yield (r=-0.508), day to emergency (r= -0.607), days to flowering (r = -0.701), days to maturity (r = -0.795), plant height (r = -803), average tuber weight (r = -0.600), and plant spread (r = -0.822) were observed. Average tuber weight associated positively and significantly (p<0.01) with plant height (r=0.716), day of flowering (r=0.590), days of maturity (r=0.786) and plant spread (r=0.713).

The relationship between marketable tuber yield and total tuber yield with average tuber weight and total tuber number per plant was positive and highly significant. This means that tuber number and tuber weight have more effect on total tuber yield. Agreement to result of Hassanpanah *et al*. (2009) observed main stem number per plant had positive correlation with marketable weight. The correlation coefficients between days to flowering days to maturity, plant spread and main stem number with average tuber weight, marketable tuber yield, plant height, total tuber number and total tuber yield were positive and significant (P<0.01).

The result indicated that the above mentioned parameters can be increased by available yield early earthing-up and with optimum planting depth in which the plant can high yield due to the critical management activity in the active vegetative growth stage of the plant. But, plant spread and days to maturity associated negatively with number of green tuber ($P<0.05$).

Line with the work of Hanbar *et al.*(2013) result show thatas it can be seen maximum depth of was cut the reason is that with increased planting depth has decreased the number of stem and reducing the number of stem tuber is reduced thus reducing the number of gland function is decreased, correlation between the average weight of the entire gland (r=0.72*)and the total number of tubers per plant (r=0.67*) is also positive and significant at the level of five percent of the significant.Similarly, Kouwenhoven (1970)result show that the depth of soil cover on the seed tuber is determined by the ridge size, planting depth and time earthing up. Earthing up, corresponding with a deep soil cover has become possible by chemical weed control increase yield.

Therefore, in the production of tubers should be given to attribute the number of stems per plant. Because the increased number of stem gland may also increase the number because the production of tubers, the tuber is the weight of the gland, the debate should be modified according to the attribute besides the increasing number of stems. This is same as the results of Majid and Roza (2011) time and depth of soiling of the plant foot had a significant effect on the percentage of potato yield per unit area. The soiling in the height of 25 to 35 cm and depth of one second of the plant height has produced the highest yield according to the results of the number of stems per unit area and the number of tubers (or glands) per unit area which are the two main components in the yield of potato.

The total yield depends on the length of the tuber growing gland the average growth of the tubers per day. The number of tubers per m^2depends on the number of main stem per $m^2$and on the number of tubers per main stem, which, in turn, decreases with the number of mainstem (Van der zaag, 1992). The result was agreement with Admir *et al.*(2014) show that the general crop performance, harvestable yield and tuber size are strongly influenced by stem number per hectare.

Table 9. Correlation analysis among yield and yield components

	AWT	UNMY	MY	TTY	TTN	SN	PH	DF	DE	DM	PS	NGT
AWT	1	-.600**	.642**	.577**	.571**	.424**	.716**	.590**	.353*	.786**	.713**	-.336*
UNMY		1	-.686**	-.508**	-.534**	-.522**	-.803**	-.701**	-.607**	-.795**	-.822**	.003
MY			1	.975**	.784**	.808**	.873**	.656**	.231	.847**	.759**	-.440**
TTY				1	.766**	.798**	.789**	.564**	.088	.761**	.648**	-.520**
TTN					1	.639**	.726**	.695**	.042	.783**	.595**	-.325
SN						1	.722**	.534**	.175	.643**	.618**	-.418*
PH							1	.729**	.439**	.907**	.900**	-.506**
DF								1	.266	.820**	.717**	-.110
DE									1	.288	.426**	-.092
DM										1	.924**	-.348*
PS											1	-.399*
NGT												1

* Correlation is significant at the 0.05 level **. Correlation is significant at the 0.01 level. DE= Days to emergence, DF=Days to flowering, DM=Days to maturity, SN=Main stem number, PH= Plant height, PS= Plant spread, TTN=Total tuber number, ATW = Average tuber weight, MTY=Marketable tuber yield, UMTY=Unmarketable tuber yield, TTY=Total tuber yield, NGT= Number of green tuber.

5. SUMMARY AND CONCLUSION

The design used was 3 x 4 factorial experiment arranged in a Randomized Complete Block, replicated three times. There are 12 treatment combinations and Jalane potato varietywere use for exponent. Potato growth, yield and yield components were collected. The result of the investigation showed that most of the parameters considered were significantly affected by both factors. Planting depth significantly affected days to 50% emergence, days to 50% flowering, days to 50% maturity, plant spread, stem number per plant and plant height. Deep planting of potato resulted delayed emergence, flowering and maturity. The maximum plant height was recorded at 12cm planting depth. The longest days to maturity was obtained from depth of planting at 12 cm combined with at 15 days earthing-up after full emergency.The number of main stems per plant generally increased with planting depth optimum and earthing-up on the time of earthing-up at 15 days to after complete plant emergency. The wide plant spread and maximum total tuber per plant recoded (50.40 cm and 10.3) respectively from time of earthing-up at 15 days to after complete plant emergency. as compare with other treatments at this treatment lead large number of total tuber per plant (10.13). The highest marketable yield was obtained from planting depth (12 cm) which was 23.57 ton ha^{-1} and at time earthing-up 15 days after full plant emergency (23.92 ton ha$^{-1)}$. The lowest marketable yield was at 10cm planting depth (18.69 ton ha^{-1}) and no earthing-up gave 17.23 ton ha^{-1}.

The interaction effect of planting depth and time of earthing-up showed a significant variation on total tuber number, number of green tuber on number of tuber of potato. The large number of total tuber number count per hill was recorded from at time of earthing-up at 15 days of after full complete plant emergency combined with planting depth at 10 cm and 12 (9.52 and 10.13), respectively. Time of earthing-up after full emergency with depth of planting at (15days x10cm, 15days x12cm, 15days x14cm, 30days x12cm, 30days x14cm and 45days x14cm) recorded the minimum number of green tubers (1.48, 1.16, 0.63, 1.23, 1, 1.56) respectively.

Time of earthing-up at 15 days to complete plant emergency was superior in the heaviest tuber weight with at optimum planting depth (12cm). Earthing-up at 15 days to complete plant emergency resulted in increased average tuber weight by 10.29% as compared to the no earthing-up. Similarly, earthing-up at 15 days to complete plant emergency showed reduced unmarketable tuber yield by 13.62 %, as compared to no earthing-up. Concerning to depth of planting, recorded unmarketable tuber yield from plots planted at optimum depth (12 cm) and deep planting (14cm) was lower by 36.87 and 16.49% respectively than obtained from shallow planting depth (10 cm).

The correlation coefficients between days to flowering and days to maturity with average tuber weight, marketable tuber yield, total tuber yield, tuber number, steam number and plant height and plant spread were positive and highly significant ($P<0.01$), were as unmarketable yield and number of green tuber were negatively and highly significant ($p<0.01$).The results of correlation show that most yield and yield components can be a good performance by early earthing-up when the plant reach active growth stage and tuber imitation period with, without go to the cut point above or below optimum planting depth which the plant can use the recourse efficiently and effectively due to the extended vegetative growth of the plant. The result indicated that increased planting depth decreased the number of stem and reducing the number of stem tuber.

Planting depth (12cm) and time of earthing-up at 15 days after complete plant emergence showed superior performance with regard yield and yield component parameters. Therefore, according to the current study, depth of planting (12cm) and the time of earthing-up at 15 days after complete plant emergence can be used for better of Jalane potato variety at Jimma area.

6. FUTURE LINE OF WORK

Since, the present study was done only for one season at one location; it would be advisable to repeat the experiment at various soil conditions, climate areas and production system to come up with final recommendations.

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8. APPENDICES

Appendix Table 1. Average tuber weight

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	89.00	44.502	13.82	**
Time Of Earthin-up	3	125.27	41.75	12.97	**
Depth of Planting x Time of Earthing-up	6	16.75	2.79	0.87	ns

R-Square	Coeff. Var.	Root MS	ATW Mean
0.79	3.88	1.79	46.13

Appendix Table 2.Unmarketable yield

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	20.45	10.22	334.29	**
Time Of Earthin-up	3	2.87	0.95	31.31	**
Depth of Planting x Time of Earthing-up	6	0.34	0.05	1.88	ns

R-Square	Coeff. Var.	Root MS	UNMY Mean
0.98	4.28	0.17	4.07

Appendix Table 3.Marketable yield

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	161.18	80.59	38.15	**
Time Of Earthin-up	3	289.93	96.64	45.75	**
Depth of Planting x Time of Earthing-up	6	20.36	3.39	1.61	ns

R-Square	Coeff. Var.	Root MS	MY Mean
0.91	7.04	1.45	20.63

Appendix Table 4.Total tuber yield

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	72.67	36.33	17.48	**
Time Of Earthin-up	3	286.98	78.99	38.00	**
Depth of Planting x Time of Earthing-up	6	19.92	3.32	1.60	ns

R-Square	Coeff. Var.	Root MS	TTY Mean
0.87	5.83	1.44	24.71

Appendix Table 5.Total tuber number

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	6.74	3.37	34.11	**
Time Of Earthin-up	3	21.51	7.17	72.49	**
Depth of Planting x Time of Earthing-up	6	2.24	0.37	3.78	**

R-Square	Coeff. Var.	Root MS	TN Mean
0.93	3.70	0.31	8.49

Appendix Table 6.Days of 50% emergency

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	121.21	60.60	37.82	**
Time Of Earthin-up	3	0.20	0.06	0.04	ns
Depth of Planting x Time of Earthing-up	6	0.03	0.005	0.00	ns

R-Square	Coeff. Var.	Root MS	DE Mean
0.84	8.46	1.26	14.96

Appendix Table 7. Main stem number

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	4.77	2.38	12.63	**
Time Of Earthin-up	3	5.95	1.98	10.49	**
Depth of Planting x Time of Earthing-up	6	0.98	0.16	0.87	ns

R-Square	Coeff. Var.	Root MS	SN Mean
0.75	12.81	0.43	3.39

Appendix Table 8.Plant height

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of planting	2	136.93	68.46	169.32	**
Time of earthin-up	3	116.47	38.82	96.02	**
Depth of Planting x Time of Earthing-up	6	1.43	0.23	0.59	ns

R-Square	Coeff. Var.	Root MS	TH Mean
0.96	1.07	0.63	58.89

Appendix Table 9.Days of 50%flowering

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	81.45	40.72	11.54	**
Time Of Earthin-up	3	117.22	39.07	11.07	**
Depth of Planting x Time of Earthing-up	6	26.22	4.37	1.24	ns

R-Square	Coeff. Var.	Root MS	DF Mean
0.79	2.95	1.87	63.53

Appendix Table 10.Days of 50%maturity

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	29.35	14.67	1932.99	**
Time Of Earthin-up	3	29.51	9.83	1295.47	**
Depth of Planting x Time of Earthing-up	6	0.27	0.04	5.95	**

R-Square	Coeff. Var.	Root MS	DM Mean
0.99	10.07	0.08	114.83

Appendix Table 11.Plant spread

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	490.54	245.27	996.09	**
Time Of Earthin-up	3	134.36	44.78	181.90	**
Depth of Planting x Time of Earthing-up	6	7.11	1.18	4.81	*

R-Square	Coeff. Var.	Root MS	PS Mean
0.99	1.13	0.49	43.69

Appendix Table 12.Number of green tuber

Source of variation	Df	SS	MS	F Value	Pr > F
Depth of Planting	2	2.71	1.35	228.31	**
Time Of Earthin-up	3	9.86	3.28	553.64	**
Depth of Planting x Time of Earthing-up	6	0.22	0.03	6.35	**

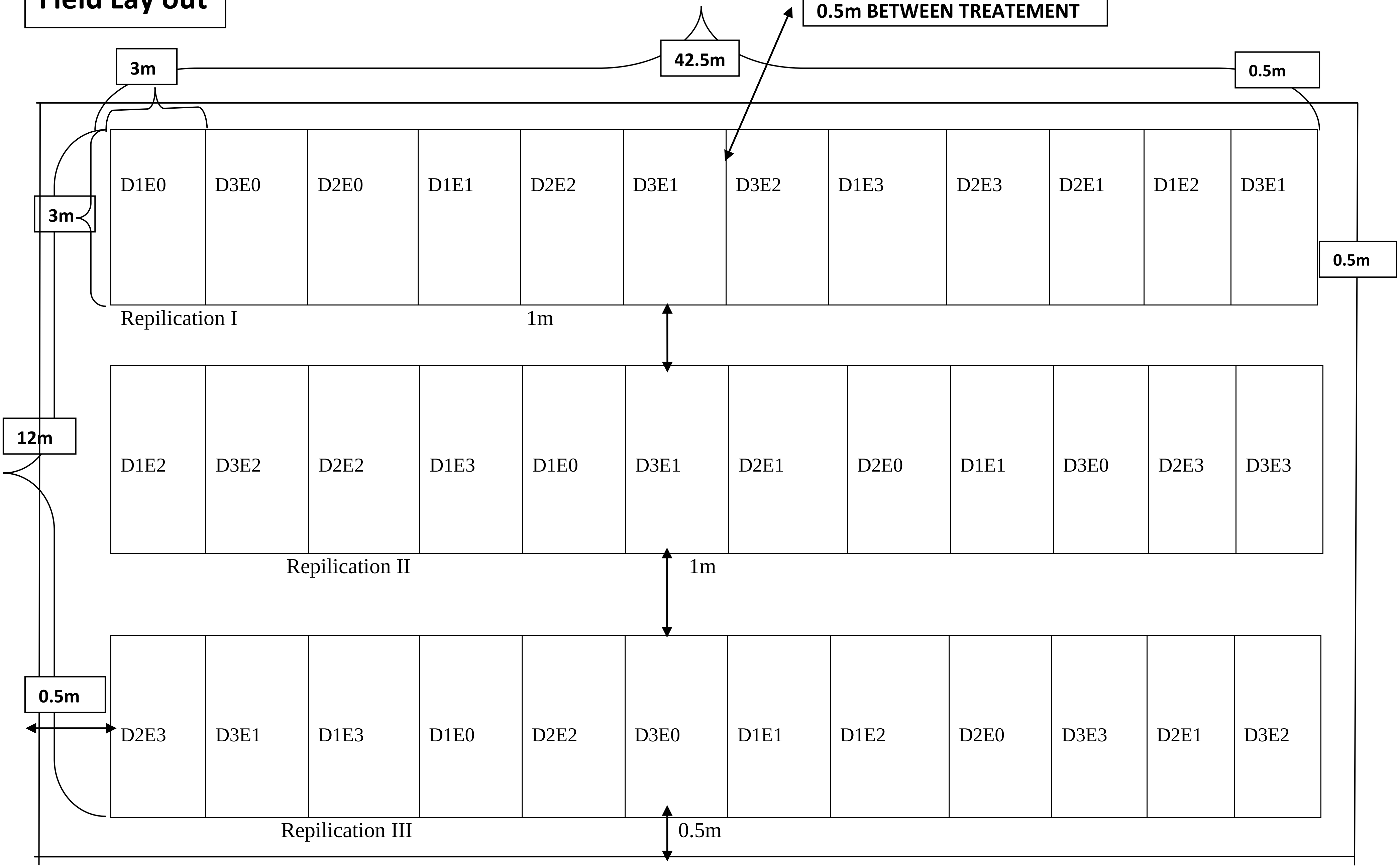
R-Square	Coeff. Var.	Root MS	NGT Mean
0.99	4.66	0.07	1.65

Appendix figure. 1. Photo Gallery of Field Experiment





Field Lay out



Were;-

1.	Planting depth at 10cm (D1) with No Earthing-up (E0)	D1E0
2.	Planting depth at 10cm (D1) with Earthing- up after 15 day after complete plant emergency (E1)	D1E1
3.	Planting depth at 10cm (D1) with Earthing- up after 30 day after complete plant emergency (E2)	D1E2
4.	Planting depth at 10cm (D1) with Earthing- up after 45day after complete plant emergency (E3)	D1E3
5.	Planting depth at 12cm (D1) with No Earthing-up (E0)	D2E0
6.	Planting depth at 12cm (D1) with Earthing- up after 15 day after complete plant emergency (E1)	D2E1
7.	Planting depth at 12cm (D1) with Earthing- up after 30 day after complete plant emergency (E2)	D2E2
8.	Planting depth at 12cm (D1) with Earthing- up after 45 day after complete plant emergency (E3)	D2E3
9.	Planting depth at 14cm (D1) with No Earthing-up (E0)	D3E0
10.	Planting depth at 14cm (D1) with Earthing- up after 15 day after complete plant emergency (E1)	D3E1
11.	Planting depth at 14cm (D1) with Earthing- up after 30 day after complete plant emergency (E2)	D3E2
12.	Planting depth at 14cm (D1) with Earthing- up after 45 day after complete plant emergency (E3)	D3E3